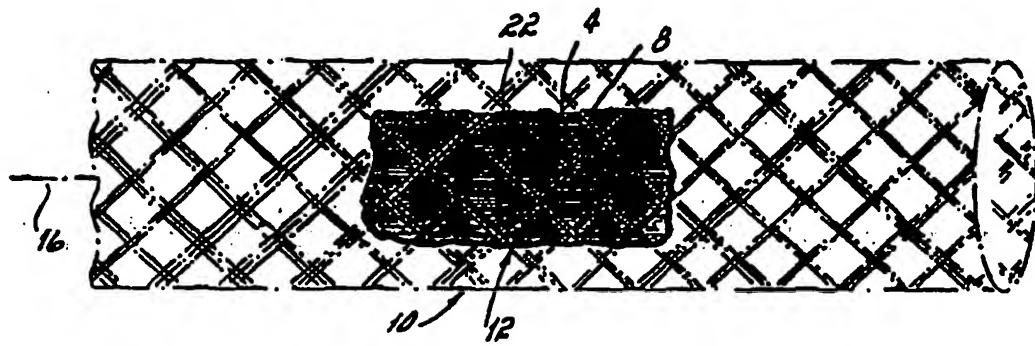




INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁶ : B29D 23/00, D04C 1/02, 1/04		A1	(11) International Publication Number: WO 98/24616 (43) International Publication Date: 11 June 1998 (11.06.98)
(21) International Application Number: PCT/US97/21800 (22) International Filing Date: 1 December 1997 (01.12.97)		(81) Designated States: CA, DE, GB, JP, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE):	
(30) Priority Data: 08/759,255 2 December 1996 (02.12.96) US 60/032,230 2 December 1996 (02.12.96) US 08/759,732 6 December 1996 (06.12.96) US 08/942,908 2 October 1997 (02.10.97) US		Published <i>With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>	
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(54) Title: BRAIDED STRUCTURE WITH ELASTIC BIAS STRANDS



(57) Abstract

A triaxial braided sleeve (10) in which the axial strands (22) are reinforcing and the bias strands (4 and 8) are elastic. Due to the elastic bias strands (4 and 8), the sleeve (10) can be used as the reinforcement in a fiber-reinforced plastic part having a tapered, curved, or other irregular shape.

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BRAIDED STRUCTURE WITH ELASTIC BIAS STRANDS

3 This application is a continuation-in-part of (1)
4 United States Patent Application Serial No. 08/759,255,
5 filed December 2, 1996 and (2) United States Patent
6 Application Serial No. 08/759,732, filed December 6, 1996.
7 This application claims the benefit of United States
8 Provisional Patent Application Serial No. 60/032,230, filed
9 December 2, 1996.

10

FIELD OF THE INVENTION

11

12 This invention relates generally to braided structures
13 and more particularly to braided structures having elastic
14 bias strands or filaments.

15

DESCRIPTION OF RELATED ART

16

17 It is known to use braided sleeving to form rigid
18 tubular parts such as fiber-reinforced plastic parts. The
19 braided sleeving is typically impregnated with a resin and
20 placed in or over a mold or mandrel or core and subjected
21 to heat and pressure to form or cure the resin and form the
22 tubular part. See U.S. Pat. Nos. 5,409,651 and 4,774,043,
23 the contents of which are incorporated by reference.

24

25 Biaxial and triaxial braided sleeving is known.
26 Triaxial braided sleeving is preferable to biaxial braided
27 sleeving in many situations because triaxial sleeving
28 generally produces a finished part which has superior
29 mechanical properties, principally strength and stiffness.

30

31 A problem with triaxial braided sleeving is that it
32 has little stretchability 1) longitudinally and 2)
33 transversely to the longitudinal axis of the sleeve. On
34 the other hand, biaxial braided sleeving is generally
35 stretchable both longitudinally and transversely

1 (radially). If expanded longitudinally, a biaxial braid
2 will contract radially; if expanded radially, it will
3 contract longitudinally. This permits biaxial braided
4 sleeving to be utilized to form tubular parts having
5 varying cross-sections, i.e. alternatively smaller and
6 larger cross-sections or diameters.

7 There is a need for a triaxial braided sleeving which
8 has the ability to conform to a tubular shape having
9 varying cross-sections. There is also a need for a fiber-
10 reinforced plastic part made from such sleeving.

11 SUMMARY OF THE INVENTION

12
13 A triaxial braided sleeve is provided, comprising
14 first bias strands extending in a first helical direction,
15 second bias strands extending in a second helical direction
16 different from said first helical direction, and axial
17 reinforcement strands, said first bias strands, second bias
18 strands and axial reinforcement strands being braided
19 together to form a triaxial braided sleeve, all of the bias
20 strands of the sleeve being elastic strands. A method of
21 making the triaxial braided sleeve is also provided, along
22 with fiber-reinforced plastic parts made utilizing the
23 invented triaxial braided sleeve.

24
25 BRIEF DESCRIPTION OF THE DRAWINGS

26
27 Fig. 1A is a schematic view of a portion of a prior
28 art bi-axial braided sleeve.

29 Fig. 1B is a schematic view of a portion of a prior
30 art triaxial braided sleeve.

31 Fig. 1 is a side schematic view of a portion of a
32 triaxial braided sleeve in accordance with the present
33 invention, with a portion shown in more detail.

34 Fig. 2 is a side elevational view of a mandrel in the
35

1 shape of an article of manufacture to be formed, for
2 example a rifle scope.

3 Fig. 3A is a fragmentary side view of the sleeve of
4 Fig. 1 being placed over the mandrel of Fig. 2.

5 Fig. 3B is a side elevational view of the sleeve of
6 Fig. 1 placed over the mandrel of Fig. 2.

7 Fig. 4 is a side elevational view of the finished part
8 manufactured according to the process of the present
9 invention.

10 Fig. 5 is a plan view of a portion of a triaxial
11 braided sleeve in accordance with the present invention.

12 Fig. 6 is a side elevational view of a utility pole.

13 DETAILED DESCRIPTION OF THE
14 PREFERRED EMBODIMENTS OF THE INVENTION

15
16 As used in the specification and claims herein, the
17 term "strand" includes a single fiber or filament or thread
18 as well as a bundle of fibers or filaments or threads.
19 Each of the following, whether twisted or untwisted, is a
20 strand: a fiber, a filament, a yarn, a tow, and a thread.
21 As used in the claims herein, "elastic" means capable of
22 being stretched repeatedly at room temperature to at least
23 about 1.4 times its original length and which, after
24 removal of the tensile force, will immediately return to
25 approximately its original length. "At least 1.4 times its
26 original length" means if the original length is 1 inch, it
27 can be stretched to a total length of at least 1.4 inches,
28 and after release it will return to approximately 1 inch.

29 With reference to Fig. 1A, there is shown a portion of
30 a known biaxial braided sleeve which is tubular. It is
31 formed of strands which are braided together. As known in
32 the art, a biaxial braided sleeve has two sets of helical
33 bias strands 14, 18. All of a plurality of first bias
34 strands 14 extend in one direction 13 parallel to one
35 another at an angle alpha to the longitudinal axis 16 of

1 the sleeve. Angle alpha is the braid angle of the bias
2 strands 14; the braid angle is the acute angle measured
3 from the longitudinal braid axis to the bias strand. All
4 of a plurality of second bias strands 18 extend in a second
5 direction 15 parallel to one another at an angle beta to
6 the longitudinal axis 16. Normally the angles alpha and
7 beta are the same and in that case either one can be used
8 to describe the braid angle.

9 Diamond braid is a known braid style, in which the
10 bias strands are braided in an over one, under one
11 configuration. In a style known as regular braid, the bias
12 strands are braided in an over two, under two
13 configuration. Regular braid and diamond braid are the
14 most common braiding styles and are well-known in the art.
15 Less common are the hercules braid (over three, under
16 three) and various satin braids. Any of these braiding
17 styles can be used in Fig. 1A.

18 Fig. 1B illustrates a portion of a known triaxial
19 braid sleeve. A triaxial braid has bias strands
20 identical to the bias strands 14, 18 in Fig. 1A, which can
21 be diamond braided, regular braided, etc. The triaxial
22 braid in addition has a plurality of axial strands 20
23 extending parallel to the longitudinal axis of the sleeve.
24 Axial strands are sometimes referred to as warps or
25 unidirectionals or laid-in strands or tows or yarns. The
26 axial strands are interwoven with the bias strands, with
27 the bias strands passing over and under the axial strands
28 as is known in the art. The number of axial strands can be
29 varied, and preferably they are spaced equidistantly or
30 regularly or uniformly around the perimeter of the sleeve,
31 as is shown in Fig. 1B. Uniform spacing provides for
32 uniform strength across the braid fabric.

33 With reference to Fig. 1, there is shown a triaxial
34 braid sleeve 10 according to the present invention. A
35 portion 12 of sleeve 10 is shown in greater detail. Sleeve

1 10 has a series of elastic bias strands 4 extending in one
2 helical direction, a second series of elastic bias strands
3 8 extending in the other helical direction, and a plurality
4 of axial strands 22 extending parallel to the longitudinal
5 axis of the sleeve. Fig. 1 shows some bias strands 4, 8 as
6 double strands; preferably each bias strand is a single
7 thread. In the present invention a triaxial braided
8 sleeving or sleeve is provided in which all of the bias
9 strands are elastic and preferably all of the axial strands
10 are structural or reinforcing such as reinforcing tows; the
11 axial strands are present to provide strength and stiffness
12 and they are inelastic or nonelastic or essentially
13 inelastic or non-stretchable and are preferably non-heat-
14 shrinkable.

15 In the present invention it is preferable to maximize
16 the amount or percentage of braid fabric or fiber material
17 or strand material in the axial direction and minimize the
18 amount or percentage of braid fabric or strand material in
19 the bias direction, because the purpose of the bias strands
20 is only to hold or maintain the axial strands in position
21 and be elastic; the bias strands are not there to provide
22 appreciable strength or stiffness. As long as sufficient
23 bias strands are present to perform their function,
24 additional bias strands would be wasteful. Therefore it is
25 preferable to minimize the number of bias strands and
26 minimize the weight and thickness of each bias strand. It
27 is desired to maximize the percentage of axial strand
28 material, which provides the strength and stiffness of the
29 braid.

30 With reference to Fig. 5, there is shown a portion 40
31 of a triaxial braided sleeve of the present invention,
32 having first bias strands 42 extending in a first helical
33 direction, second bias strands 44 extending in a second
34 helical direction, and axial reinforcement strands or tows
35 46 (such as 12K carbon) extending parallel to the

1 longitudinal axis of the sleeve.

2 The axial strands or reinforcement strands are
3 preferably fiberglass, carbon or aramid (Kevlar), less
4 preferably ceramic, ultrahigh molecular weight polyethylene
5 (such as Spectra brand), other synthetics such as acrylic,
6 nylon, rayon, polypropylene, polyamide, and polyester,
7 natural fibers such as cotton, PTFE, metals, thermoplastic
8 yarn, and mixtures or hybrids thereof, such as
9 fiberglass/carbon. The fiberglass strands or tows are
10 preferably E-glass (texturized or non-texturized) or S-
11 glass (such as S-2 glass), as known in the art, preferably
12 37 to 1800 yield, more preferably 450 to 1200 yield,
13 commonly 112, 450, 827, 1200 and 1800 yield. These are
14 known in the art and are available from Owens Corning
15 Fiberglass and PPG, such as PPG's 2002-827 Hybon and Owens
16 Corning's Product No. 111A 275. The carbon strands or tows
17 are preferably 3K, 6K, 12K and 48K, both commercial grade
18 and aerospace grade, available from Hexcel, Toho, Toray,
19 Amoco, and Grafil, including AS4 carbon and Hexcel Product
20 No. IM7-GP12K. The aramid strands or tows are preferably
21 Kevlar brand from DuPont, Kevlar 29 and Kevlar 49,
22 preferably 200 to 1500 denier, such as 200, 380, 1140,
23 1420, and 1500 denier. These strands can have sizing, such
24 as Nos. 964 or 965 as known in the art. These structural
25 or reinforcement strands typically have 1-6% strain to
26 failure (ASTM D2101), meaning they will stretch 1-6% and
27 then break; as can be seen they are essentially inelastic.
28 With reference to Fig. 5, the axial strands 46 are
29 preferably all the same, less preferably they can vary,
30 such as every fifth one or every other one being carbon and
31 the rest fiberglass, or the strands on one side of the
32 sleeve being heavy fiberglass and the strands on the other
33 side of the sleeve being lighter fiberglass.

34 The elastic bias strands are preferably elastic
35 threads or elastic yarns as known in the art. An elastic

1 thread typically has a core of an elastomer such as natural
2 or synthetic rubber or similar elastomer or spandex and may
3 or may not have a cover or serving of natural or synthetic
4 fibers or fabric, typically cotton, nylon or polyester. If
5 the elastic thread is uncovered, it preferably will stretch
6 at least 200, 400, 500, 600 or 700%; it preferably will
7 have 100-800%, more preferably 400-800%, maximum stretch or
8 elongation at break. If a one inch thread has 700% maximum
9 stretch, that means it will stretch at room temperature to
10 eight inches and then break or fail; since it is elastic it
11 will return to approximately one inch length if released
12 before breakage. If the elastomer or rubber or spandex
13 core is covered, the elastic thread preferably has at least
14 70, 100, 200, or 300%, or about 100-150%, 100-200%, or 100-
15 400%, maximum stretch or elongation at break; if a one inch
16 thread has 130% maximum stretch, that means that it will
17 stretch to a maximum of 2.3 inches before failing or
18 tearing the cover. The cover acts to control or limit the
19 stretch (which may make braiding easier), imparts
20 additional tensile strength, and frequently makes the
21 thread slipperier; covered thread is preferred where these
22 characteristics are useful.

23 The elastic thread has a maximum stretch of at least
24 40%, more preferably at least 75%, more preferably at least
25 about 90%, more preferably at least 100%, typically at
26 least 100, 200, or 300%, or about 100-200, 100-400, or 100-
27 800, % maximum stretch. The elastic thread preferably has
28 a weight of 250 to 6000, more preferably 700-4400, yds/lb.
29 Suitable elastic threads for use in the present invention
30 include No. SE144 (rubber core with nylon cover, 785
31 yds/lb., having 130% max. stretch), uncovered Lycra brand
32 spandex having 700% max. stretch, 560-650 denier, and No.
33 135A9J (Lycra brand spandex core with polyester cover, 4200
34 yds/lb., having 120% max. stretch), available from Supreme
35 Corp., Hickory, N.C.

1 The present invention is made on conventional braiding
2 machines or braiders having 8 to 800 or more carriers,
3 typically having 80 to 400 or 500 or 600 carriers, for
4 example 144 or 208 carriers, although braiders with 16 to
5 80 carriers are useful for smaller sleeves such as for a
6 golf club shaft. A conventional 144 carrier braider has 72
7 axial positions. As known in the art, a conventional
8 braider has one axial position for every two carriers. In
9 producing the invented braid preferably all of the axial
10 positions on the braider are used, in order to maximize the
11 percentage of the braid fabric in the axial position or
12 direction. Less preferably, less than all the axial
13 positions are utilized.

14 When a conventional 144 carrier braider is run
15 utilizing all 144 carriers and all 72 axial positions, a
16 regular braid is produced having 72 bias strands extending
17 in one bias direction, 72 bias strands extending in the
18 other bias direction, and 72 axial strands running
19 longitudinally. When that 144 carrier braider is run
20 utilizing only 72 of the carriers (36 in one bias direction
21 and 36 in the other bias direction), a diamond braid is
22 produced. When that 144 carrier braider is run utilizing
23 only 36 of the carriers (18 in one bias direction and 18 in
24 the other bias direction), a braid referred to herein as a
25 double diamond braid is produced. When that 144 carrier
26 braider is run utilizing only 18 of the carriers (9 in one
27 bias direction and 9 in the other bias direction), a braid
28 referred to herein as a triple diamond braid is produced.
29 Regular, diamond, double diamond, and triple diamond braids
30 can be produced on braiders having other numbers of
31 carriers (eg., 80 carriers, 208 carriers, 400 carriers) by
32 using the same ratios. As used in the specification and
33 claims herein, diamond, double diamond, and triple diamond
34 shall have the meanings as described above.

35 The invented braid is preferably made on a regular

1 braider (a braider which makes regular braid when its full
2 compliment of carriers are utilized) utilizing 1/2 to about
3 1/75, more preferably 1/2 to about 1/60, more preferably
4 about 1/4 to about 1/40, more preferably about 1/8 to about
5 1/20, alternatively about 1/12 to about 1/16, of the full
6 compliment of carriers, preferably not more than 1/2 or 1/4
7 or 1/8 or 1/12 or 1/16, and preferably not less than 1/75
8 or 1/60 or 1/40 or 1/20, of the full compliment of
9 carriers, subject to the condition that the carriers
10 utilized are equally spaced and symmetrically arrayed with
11 an equal number of carriers going in each direction. For
12 example, a 600 carrier braider could utilize 1/60, or ten
13 carriers, with five going in each direction and
14 symmetrically arrayed. Regarding the invented braid, a
15 triple diamond braid is preferable to a double diamond
16 braid, which is preferable to a diamond braid.

17 As used in the specification and claims herein, an
18 "axial position strand" is all of the fibers or filaments
19 or strands or threads or tows going through one axial
20 position on a braider, and a "bias carrier strand" is all
21 of the fibers or filaments or strands or threads or tows on
22 a single carrier of a braider. In the present invention
23 each axial position strand will typically be one or two or
24 three or four tows of reinforcing filaments and each bias
25 carrier strand will typically be one elastic thread. In
26 the invented braid the ratio of axial position strands to
27 bias carrier strands (including, by definition, those bias
28 strands going one way and those bias strands going the
29 other way) is preferably at least 1:1, more preferably at
30 least 2:1, more preferably at least 4:1, more preferably at
31 least 6:1, alternatively at least 8:1 or 10:1 or 20:1 or
32 30:1, preferably not more than 37.5:1 or 30:1,
33 alternatively not more than 20:1 or 10:1 or 8:1. For
34 example, a 600 carrier braider using ten carriers and 300
35 axial positions produces a braid having a ratio of axial

1 position strands to bias carrier strands of 300:10 or 30:1.
2 Preferably, whenever less than all the carriers or axial
3 positions are used, those that are used are spaced as
4 evenly or equidistantly or uniformly around the braider as
5 possible.

6 As an option, a portion of the axial positions can be
7 one reinforcing strand and the other portion of the axial
8 positions can be a different weight or type of reinforcing
9 strand; for example on a snowboard it may be desirable to
10 have more reinforcing on the bottom than on the top. This
11 is achieved by loading thicker, heavier fiberglass on the
12 axial positions around one half of the braider deck and
13 loading a lighter fiberglass or carbon, etc. on the axial
14 positions around the other half of the braider deck. The
15 resulting sleeve would have a bottom half (for the bottom
16 of the snowboard) heavily reinforced with fiberglass and a
17 top half (for the top half of the snowboard) with less
18 fiberglass reinforcing or alternatively lighter carbon or
19 aramid reinforcing. These same principles can be applied
20 to produce differentially or asymmetrically reinforced
21 sleeving for other products such as curves in furniture,
22 different sides of hockey sticks, different sides of snow
23 skis, etc. A side facing or experiencing more stress may
24 be more heavily reinforced. Stated more generally, the
25 braided sleeve would have a first axial position strand of
26 a first material and a second axial position strand of a
27 second material, the first material being different from
28 the second material in type (for example, one is fiberglass
29 and the other is carbon or fiberglass/carbon) or weight
30 (for example, one is 112 yield fiberglass and the other is
31 827 yield fiberglass). Preferably, at least 10%, more
32 preferably 20%, more preferably 30%, more preferably 40%,
33 more preferably 45%, more preferably about 50%, of the
34 axial position strands are of the first material, with the
35 remaining axial position strands being of the second

1 material; optionally some of the remaining axial position
2 strands can be of a third material, a fourth material, etc;
3 preferably at least 10%, more preferably 20%, more
4 preferably 30%, more preferably 40%, more preferably 45%,
5 more preferably about 50%, of the axial position strands
6 are of the second material.

7 When the braider is set up to produce the invented
8 braid, elastic strands are loaded onto the carriers being
9 utilized (preferably one end or thread per carrier, less
10 preferably more than one end or thread per carrier) and set
11 at light to medium spring tension. Reinforcement strands
12 (such as 112 or 450 yield E-glass or 12K carbon) are placed
13 in the axial positions, typically one, two, three, or four
14 ends per position (although up to about 8 ends per position
15 can be used). The amount of reinforcement strands is
16 generally a function of the amount of reinforcing needed in
17 the finished part, which is generally known in the art.
18 Preferably the reinforcement axial strands are run from
19 supplier packages under the machine rather than from
20 spools. The axial strands are set to very light to no
21 tension. The machine is then set to produce a braid angle
22 of 35-75°, more preferably 45-75°, more preferably 40-70°,
23 more preferably 45-65°, more preferably 50-63°, more
24 preferably 55-60°, typically 57° or 60°.

25 It is preferred to minimize the weight percent of the
26 braided fabric which is elastic strands; preferably elastic
27 strands make up 0.1-20 (or more), more preferably 0.5-15,
28 more preferably 1-10, more preferably 2-6, preferably less
29 than 20, more preferably less than 10, more preferably less
30 than 7.5, more preferably less than 5, more preferably less
31 than 3, weight percent of the braided fabric, with the
32 balance being reinforcement strands. The invented braided
33 sleeve, in its relaxed state, is preferably about 0.01-24,
34 more preferably about 0.1-8, more preferably about 0.5-5,
35 inches in diameter.

1 The braid produced can then be used to produce fiber-
2 reinforced plastic parts as are well-known in the art. The
3 braided sleeving can be impregnated with a resin (such as
4 epoxy, polyester, vinyl ester, polyurethane, phenolic,
5 nylon, acrylic, and other thermosets or thermoplastics) and
6 placed in or over a mold or substrate or base form or core
7 or mandrel and subjected to heat and/or pressure to form or
8 cure the resin and form the part. The processes that can
9 be utilized include resin transfer molding (RTM) and Scrimp
10 brand molding, hand lay-up, compression molding, pultrusion
11 molding, "B stage" forming, and autoclave molding, all as
12 known in the art. The resins and molding techniques that
13 can be used to make reinforced plastic parts using the
14 invented braided sleeving are well-known in the art and
15 are, for example, described and referred to in U.S. Pat.
16 Nos. 5,419,231; 5,409,651; 4,283,446; 5,100,713; 4,946,721;
17 and 4,774,043 and the U.S. patents mentioned in those
18 patents, the disclosures of all of which are incorporated
19 herein by reference.

20 Figs. 2-4 illustrate a method of manufacturing an
21 article incorporating the sleeve of Fig. 1. Fig. 2
22 illustrates a mandrel 24 generally in the shape of the
23 article to be formed, for example, a tube scope to be
24 mounted on a firearm. The mandrel 24 has two end sections
25 26, 28 of a relatively large diameter and a middle narrow
26 section 30 having a much smaller diameter. In the middle
27 of the middle section 30 is an annular enlargement 32 of a
28 larger diameter than the remainder of middle section 30 but
29 of a smaller diameter than the end sections 26, 28.
30 Although one specific mandrel having cross-sections of
31 differing diameters is illustrated, many variations thereof
32 may be used to form many different shaped parts.

33 Fig. 3A illustrates the sleeve of Fig. 1 being placed
34 over the mandrel of Fig. 2 from left to right in the
35 direction of arrows 34. Due to the elastic bias strands of

1 braided sleeve 10, the sleeve may be radially expanded over
2 the different portions of the mandrel and maintain a snug
3 fit throughout the entire length of the mandrel, and
4 maintain the axial strands 22 equidistantly or equally or
5 uniformly spaced around the perimeter of the various cross-
6 sections of the mandrel, thus providing more uniform
7 strength across the finished part. The invented axial
8 reinforcing sleeve can be stretched over tapered, curved,
9 or other irregular shapes, distributing the axial
10 reinforcements uniformly around the perimeter of the part.
11 The relaxed diameter of the sleeve is selected so that it
12 is no larger than the narrowest diameter of the mandrel.
13 When the sleeve is stretched over the mandrel or core or
14 form or substrate, preferably its final stretched state is
15 not more than 50, less preferably 75, less preferably 100,
16 less preferably 200, percent more than its relaxed state,
17 since greater stretching more greatly separates the axial
18 strands, resulting in less strength and stiffness, although
19 the sleeve can in less critical applications be stretched
20 up to 700 and 800 percent and more. The sleeve is
21 particularly effective for cores or mandrels whose greatest
22 cross-sectional perimeter (perimeter at the cross section)
23 is not more than 50, less preferably 75, less preferably
24 100, less preferably 200, percent more than its least
25 cross-sectional perimeter, for the reason set forth above.
26 As can be seen in Fig. 3B, the sleeve covers the entire
27 length of the mandrel.

28 At some point in the process the sleeve is
29 preimpregnated ("prepreg"), impregnated or covered or
30 coated with resin and the part is then cured or formed,
31 typically via application of heat and/or pressure, all as
32 known in the art previously described. The part is cooled
33 and the mandrel is typically removed. Alternatively a
34 substrate or form (such as a polyurethane foam core or
35 other foam core) is used which functions as a mandrel but

1 is not removed and becomes part of the finished article;
2 this is also known in the fiber-reinforced plastic art.
3 The resulting tubular article 36 is shown in Fig. 4. Fig.
4 6 shows a tapered hollow utility pole or tube 48 made in a
5 similar manner.

6 Fiber-reinforced plastic parts known in the art having
7 varying cross sections can be advantageously made using the
8 present invention, including golf club shafts, lighting
9 poles, hollow utility poles or tubes, pipes, tubing with
10 bends and diameter changes, ducting for aircraft such as
11 air conditioning ducting, electric transmission poles, ski
12 poles, fishing rods or poles, flag poles, push poles for
13 boats (tapered at each end), bicycle parts, including
14 seats, wheels and frames, hockey sticks, field hockey
15 sticks, snowboards, wakeboards, snow skis, water skis,
16 firearm (such as rifle) scopes, tapered poles, tapered bars
17 or rods, connectors for tubing, and parts having complex
18 shapes like parts of a chair or commercial furniture such
19 as the corners or bends.

20 Although the preferred embodiments of this invention
21 have been shown and described, it should be understood that
22 various modifications and rearrangements of the parts may
23 be resorted to without departing from the scope of the
24 invention as disclosed and claimed herein.

WHAT IS CLAIMED IS:

1 1. A triaxial braided sleeve comprising first bias
2 strands extending in a first helical direction, second bias
3 strands extending in a second helical direction different
4 from said first helical direction, and axial reinforcement
5 strands, said first bias strands, second bias strands and
6 axial reinforcement strands being braided together to form
7 a triaxial braided sleeve, all of the bias strands of the
8 sleeve being elastic strands.

1 2. A sleeve according to claim 1, wherein each of
2 said axial reinforcement strands is of a material selected
3 from the group consisting of fiberglass, carbon, aramid,
4 and mixtures or hybrids thereof.

1 3. A sleeve according to claim 1, wherein each bias
2 strand of said sleeve is an elastic thread.

1 4. A sleeve according to claim 1, said sleeve being
2 not more than 7 weight percent bias strands and the
3 remaining weight percent being axial reinforcement strands.

1 5. A sleeve according to claim 1, said sleeve having
2 been produced on a regular braider utilizing not more than
3 1/4 of the full compliment of carriers of said regular
4 braider.

1 6. A sleeve according to claim 1, said sleeve having
2 been produced on a regular braider utilizing not more than
3 1/8 of the full compliment of carriers of said regular
4 braider.

1 7. A sleeve according to claim 1, said sleeve having
2 a ratio of axial position strands to bias carrier strands
3 of at least 2:1.

1 8. A sleeve according to claim 1, said sleeve having
2 a ratio of axial position strands to bias carrier strands
3 of at least 4:1.

1 9. A sleeve according to claim 3, wherein each said
2 elastic thread is capable of being stretched to at least
3 about 1.9 times its original length.

1 10. A sleeve according to claim 1, each of said first
2 bias strands and each of said second bias strands having a
3 braid angle of 45-75°.

1 11. A sleeve according to claim 9, said elastic
2 thread being covered elastic thread.

1 12. A sleeve according to claim 1, said sleeve having
2 a first axial position strand of a first material and a
3 second axial position strand of a second material, said
4 first material being different from said second material in
5 type or weight.

1 13. A sleeve according to claim 12, said sleeve
2 having a plurality of axial position strands, at least 10%
3 of the axial position strands of the sleeve being of said
4 first material, at least 40% of the axial position strands
5 of the sleeve being of said second material.

1 14. A sleeve according to claim 13, at least 30% of
2 the axial position strands of the sleeve being of said
3 first material.

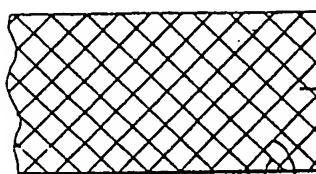
1 15. A method of making a triaxial braided sleeve
2 comprising the steps of providing a regular braider having
3 a full compliment of carriers and having a plurality of

4 axial positions, providing each of a first set of carriers
5 with elastic thread, said first set of carriers being not
6 more than 1/4 of said full compliment of carriers,
7 providing each of said plurality of axial positions with a
8 reinforcement strand, and operating said braider to produce
9 a triaxial braided sleeve having bias strands and axial
10 reinforcement strands, each of said bias strands being an
11 elastic thread.

1 16. A fiber-reinforced plastic part comprising a
2 triaxial braided sleeve in a resin matrix, said sleeve
3 comprising first bias strands extending in a first
4 direction, second bias strands extending in a second
5 direction, and axial reinforcement strands, all of the bias
6 strands of the sleeve being in their natural state elastic
7 strands.

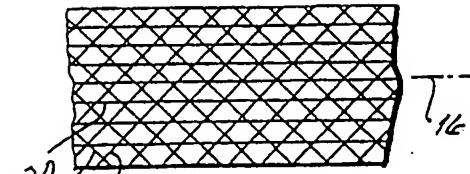
1 17. A part according to claim 16, wherein said part
2 is a tapered tube.

1 18. A part according to claim 16, wherein said part
2 is a utility pole.



BI-AXIAL PRIOR ART

FIG. 1A



TRI-AXIAL PRIOR ART

FIG. 1B

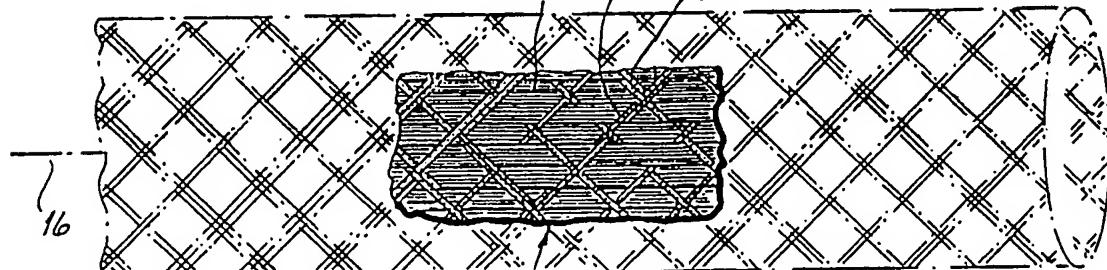


FIG. I

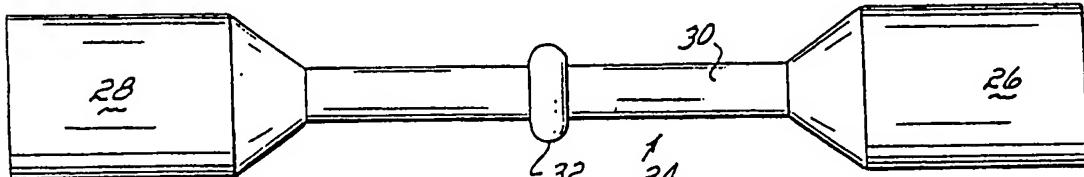


FIG.2

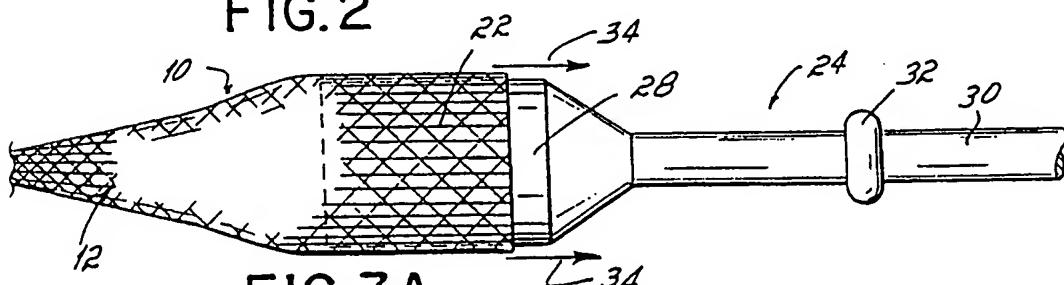


FIG. 3A

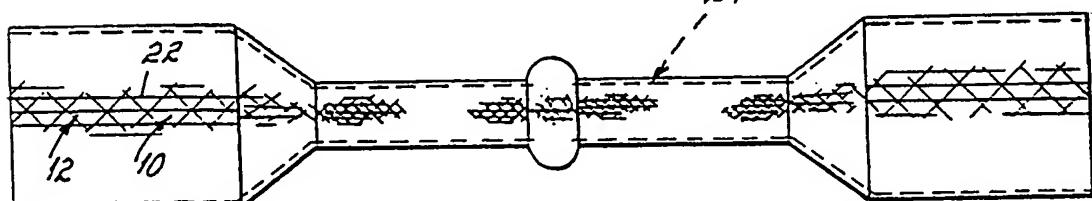


FIG. 3B

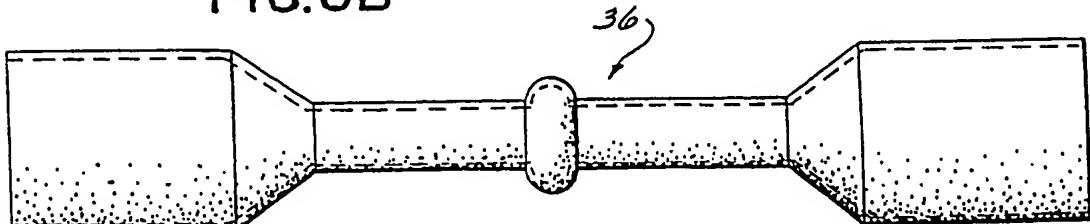
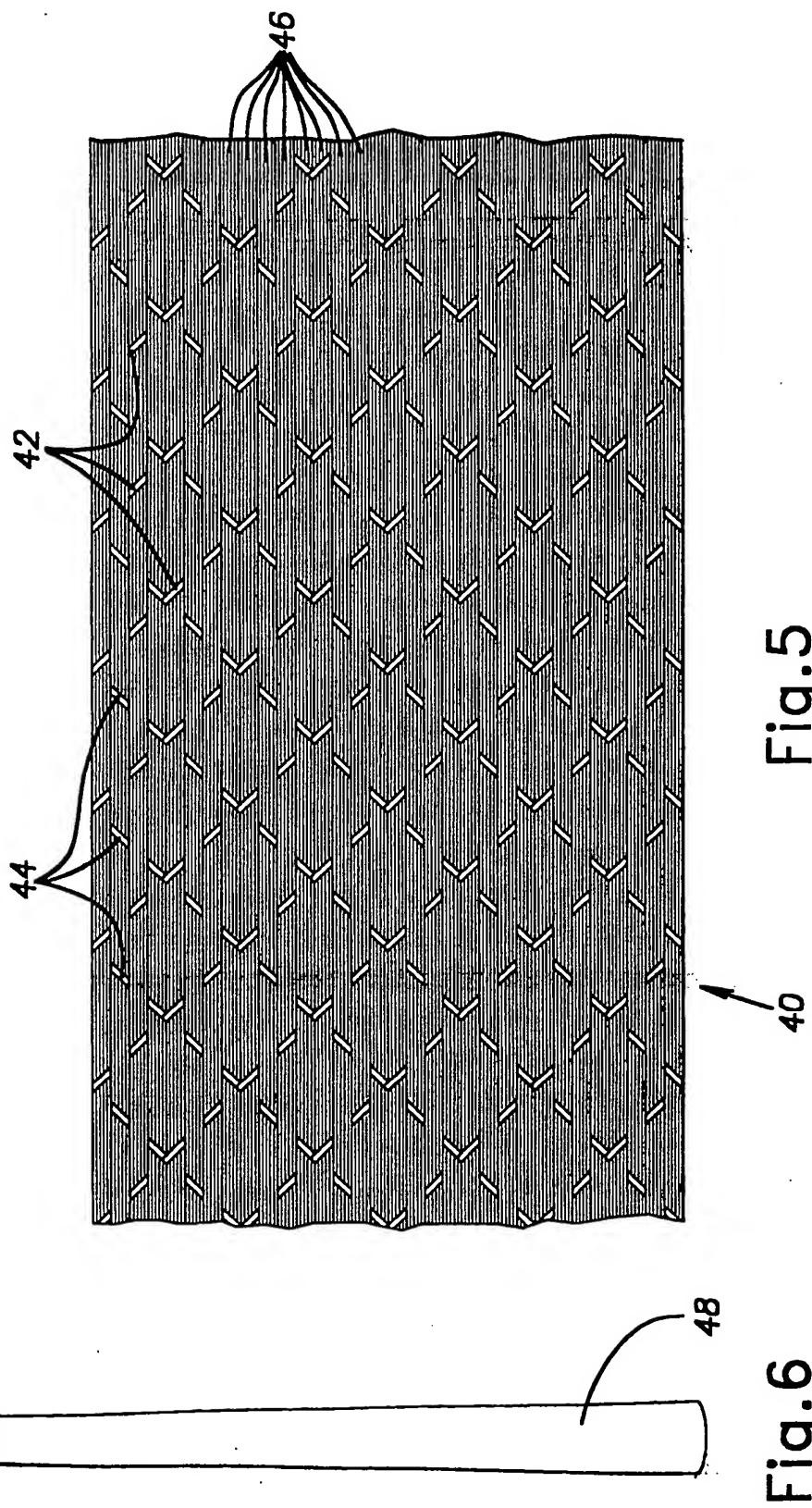


FIG. 4



INTERNATIONAL SEARCH REPORT

International application No.

PCT/US97/21800

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :B29D 23/00; D04C 1/02, 1/04

US CL :87/1, 2, 9; 428/34.5, 36.3, 36.9, 36.92

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 87/1, 2, 9; 428/34.5, 36.3, 36.9, 36.92

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS

search terms: triaxial, braid?, elastic, elastomeric

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4,834,755 A (SILVESTRINI et al.) 30 May 1989.	1
A	US 4,610,688 A (SILVESTRINI et al.) 09 September 1986.	1
A	US 4,533,321 A (KIDD et al.) 06 August 1985.	1

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See patent family annex.

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- "Z" document member of the same patent family

Date of the actual completion of the international search

25 MARCH 1998

Date of mailing of the international search report

13 APR 1998

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